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(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 916 074 B1

(12) EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention of the grant of the patent:
30.07.2003 Bulletin 2003/31

(21) Application number: 98930745.9

(22) Date of filing: 28.05.1998

(51) Int Cl.7: G01D 5/14, G01B 7/30

(86) International application number:
PCT/EP98/03149

(87) International publication number:
WO 98/054547 (03.12.1998 Gazette 1998/48)

(54) **MAGNETIC ROTATION SENSOR**

MAGNETISCHER DREHGEBER

CAPTEUR DE ROTATION MAGNETIQUE

(84) Designated Contracting States:
DE FR GB IT

(30) Priority: 29.05.1997 US 47905 P

(43) Date of publication of application:
19.05.1999 Bulletin 1999/20

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GB-A- 2 143 328

EP 0 916 074 B1

Printed by Jouve, 75001 PARIS (FR)

Description

Field of the invention

[0001] The invention is in the field of contactless angle measurement. It concerns a method and an arrangement according to the generic parts of the corresponding independent claims which method and arrangement serve for detecting the rotation position of a rotor with the aid of a magnetic source connected to the rotor and of stationary sensor means for measuring the magnetic field of the magnetic source. The method and arrangement according to the invention are applicable e.g. for rotary switches or for rotary position detection.

Background of the invention

[0002] The measurement of rotation angle is required in various applications, such as manual electrical switches or position detection of a motor (see e.g. DE 38 26 408 A1). Depending on cost and accuracy constraints, this task can be accomplished by various methods, such as mechanical contacts, optical encoders, or magnetic encoders. Modern integrated circuit technology offers the possibility to integrate magnetic sensors and their readout and angle calculation electronics on one die. This allows embodiments of detectors of mechanical rotation which consist of a permanent magnet attached to the rotor and monolithically integrated sensor means attached to a stator, at competitive cost, yet good performance. The absence of mechanical contact between the rotor with the magnet and the stator with the sensor means allows for hermetic encapsulation of the sensor means. This permits wear free angle measurements under harsh environmental conditions.

[0003] The robustness of the angle measurement against mechanical tolerances, against device variation, and against external electromagnetic fields, while keeping fabrication cost low, is a major performance criterion.

[0004] The object of the invention is to show a method and to create an arrangement for detecting the rotation position of a rotor using a magnetic source connected to the rotor and stationary magnetic field sensor means for measuring the magnetic field of the magnetic source, which method and arrangement allow, compared to known such methods and arrangements, increased robustness against sensitivity and offset variations of the sensor means, against external magnetic fields and furthermore against mechanical tolerances regarding the relative positions of the sensor means and the magnetic source.

[0005] This object is achieved by the method and the arrangement as defined by the claims.

Summary of the invention

[0006] The inventive arrangement for contactless angle measurement comprises a magnetic source mounted to the rotating part (rotor) rotatable around a rotation axis and an array of magnetic sensors mounted on the non-rotating part (stator). The magnetic source is arranged such that the magnetic field has no rotational symmetry relative to the rotation axis. The sensor means consists of at least three sensors arranged in at least two sensor pairs, whereby each sensor may be replaced by a cluster of sensors (plurality of sensors arranged very close to each other). The sensors, e.g. Hall sensors, are arranged in such a way that at least the two sensors of each sensor pair are sensitive to parallel components of the magnetic field. Furthermore, the sensors are such arranged that connecting lines each connecting two sensors of one sensor pair have projections in a plane perpendicular to the rotation axis which are angled relative to each other. Advantageously, the sensors of each pair are positioned in one plane perpendicular to the rotation axis, e.g. all pairs in the same plane.

[0007] According to the inventive method, the mechanical angle (rotation position of the rotor) is determined by calculating at least one ratio of two differential signals of one sensor pair each (the differential signal of a sensor pair being the difference between the signals of the two sensors of the pair) and by comparing the calculated ratio with a predetermined (calculated or experimentally determined) function of said ratio versus the rotation angle. If instead of single sensors clusters of sensors are used it is the mean value of the sensor signals of the cluster which is used for calculating the differential signals.

[0008] This method yields an angle determination which is insensitive to variations common to the two sensors of each pair (e.g. offset) and to sensitivity variations common to all sensors contributing to one ratio, as well as to external magnetic fields.

[0009] For reducing or even suppressing the influence of mechanical misalignment of the rotating magnetic source and the sensor array with respect to each other and to the rotation axis, the magnetic source and the sensor array are such designed and such arranged that the magnetic field component to be measured at any possible sensor location is described by the product of a first order polynomial within a planar surface substantially perpendicular to the rotation axis (magnetic field changing linearly within such a planar surface, i.e. having no curvature), and a function perpendicular to said planar surface, which function is essentially the same for all sensor locations and is advantageously

well approximated by a linear function.

[0010] In addition to providing information about the angle of mechanical rotation, the field of the magnetic source can be used to hold the rotor in place by adding a ferromagnetic yoke to the stator. Said yoke, shaping the magnetic field of the rotor, further enhances the insensitivity of the device against mechanical misalignment.

Short description of the drawings

[0011] The invention is described in more detail referring to the following Figures, wherein:

Figure 1 shows a diagrammatic cross-sectional view of an exemplary embodiment of the inventive arrangement for determining the rotation position of a rotor 2 rotatable around a rotation axis 1, the arrangement comprising a rotor 2 containing a magnetic source 2.1, and a stator 3 with a planar array of Hall devices 4 to 7, e.g. monolithically integrated with signal conditioning and angle calculation electronics on an integrated circuit;

Figure 2 shows an exemplary array of two sensor pairs 4/5 and 6/7 as seen along the axis of rotation 1, wherein each sensor pair is essentially located within a plane perpendicular to the axis of rotation 1 and wherein both pairs may but need not share the same plane;

Figure 3 shows the magnetic field component parallel to the axis of rotation (lines of equal field strength in square of 2x2mm centered between north and south pole), as generated by a bar magnet, at a distance of some 0.5mm from the surface of the magnet, whereby the region enclosed in the circle 30 (area of ca. 120µm diameter) complies to the requirements as given for robustness against mechanical tolerances;

Figure 4 shows a cross section of a further exemplary embodiment of the inventive arrangement for measuring the angle of mechanical rotation about an axis 1, the arrangement comprising a rotor 2 with two bar magnets 8 and 9 and a ferromagnetic yoke 10 and a stator 3 with an array of Hall sensors 4, 5, 6 and a ferromagnetic yoke 11, whereby the ferromagnetic yoke 11 serves for holding the rotor 2 in place and for shaping the magnetic field in the vicinity of the sensors.

Description of the preferred embodiments

[0012] A preferred embodiment of the inventive arrangement is illustrated in Figure 1 (section along rotation axis 1). The arrangement comprises a magnetic source 2.1 attached to a rotor 2 rotating about an axis 1 and an array of e.g four magnetic field sensors of which three 4, 5 and 6 are visible. The sensors are located within the field of the magnetic source. The field sensors are sensitive to the magnetic field or to a particular component thereof, to be denoted as $B_\perp$. The field sensors are e.g. Hall sensors being sensitive to the component of the magnetic field perpendicular to their sensor plane and they are integrated in one die preferably together with readout and angle calculation electronics.

[0013] As shown in Figure 2 (top view), the exemplary sensor array comprises two pairs of sensors 4/5 and 6/7, preferably located within one plane, which plane is oriented substantially perpendicular to the rotation axis 1 of the rotor 2. The connecting lines between the two sensors of each pair must not all be parallel. It is possible that different sensor pairs share one common sensor (e.g in an array with three sensors only).

[0014] The signal measured by each sensor is proportional to $B_\perp$ at the sensor location. For each pair of sensors, the difference of the two sensor signals is generated. The angle of rotation, to be denoted as Φ, is calculated as a function of a ratio of difference signals. This method is insensitive to multiplication of the sensor signals with a factor common to all sensors whose measured signals are utilized for calculating one ratio of differences, as well as to the addition of a signal common to a pair of sensors, for instance due to sensor offset or external magnetic fields. An ambiguity of angle Φ of ±180° introduced by using said method to determine the angle is eliminated by utilizing a plurality of ratios of differences to determine the angle, or by evaluating the sign of the difference signals of at least one of the sensor pairs, i.e. evaluating the difference signal as a positive or a negative value.

[0015] One preferred embodiment of a sensor array for an inventive arrangement comprises two pairs of sensors, the sensors of each pair being located at opposing corners of a square which square is arranged perpendicular to and symmetrical with respect to the rotation axis 1 of the rotor 2, whereby all sensors measure parallel components of the field, e.g. components perpendicular to the plane of the square. In this particular case, the mechanical angle Φ is given by:

$$\Phi = \text{arc tan}\{(S_7 - S_6)/(S_5 - S_4)\} = \text{arc cot}\{(S_5 - S_4)/(S_7 - S_6)\}.$$

[0016] More sensor pairs can be added for improved accuracy.

[0017] Low cross-sensitivity of the measured rotation angle Φ determined by the inventive method to mechanical translation of the magnetic source and/or the sensor array with respect to each other and to the axis of rotation is achieved by designing the inventive arrangement such that in the vicinity of each possible sensor location, the magnetic field is linear within the plane in which the sensors are arranged, and such that at each possible sensor location the change of the magnetic field parallel to the rotation axis is governed by substantially the same function.

[0018] The measures as indicated above for substantially suppressing the effect of translation are explained as follows: Let V_i denote the volume in a rotating coordinate frame attached to the magnetic source which encloses the position of both field sensors of one sensor pair, labeled by i, for any rotational angle Φ and any mechanical displacement that may occur under permitted operating conditions of the angle detector. Let x and y denote rectilinear coordinates perpendicular to the axis of rotation, z the linear coordinate parallel to the axis of rotation. The field component of the magnetic source measured by the sensors within the volume V_i is essentially described by a function $B_\perp(x,y,z) = B_i^0 + a_i \cdot x \cdot f_i(z)$, with constants B_i^0 and a_i and function $f_i(z)$ independent of x and y. The functions $f_i(z)$ and $f_j(z)$, associated to sensor pairs i and j whereof the ratio of differences is calculated to determine the angle Φ are essentially equal. Mechanical translation of the sensor array or the magnetic source perpendicular to the axis of rotation results in a common mode signal of sensor pairs, which is substantially cancelled by utilizing difference signals. Mechanical translation of the sensor array or the magnetic source parallel to the axis of rotation (i. e. a change in distance between magnetic source and sensor array) does not influence the measured angle Φ as the ratio of two differential signals remains essentially unchanged with z due to the condition on the set of $f_i(z)$ functions stated above.

[0019] For achieving low sensitivity or even insensitivity against tilt, i.e. mechanical rotation of the magnetic source and/or the sensor array about an axis (axis of tilt) perpendicular to the rotation axis, the inventive arrangement is designed such that in the vicinity of each possible sensor location, the change of the magnetic field parallel to the rotation axis is governed by substantially the same linear function and the sensors of each pair are arranged such that the connecting lines connecting two sensors of one pair are perpendicular to the rotation axis and are intersected by the rotation axis in their middle.

[0020] The measures as indicated above for substantially suppressing the effect of tilt are explained as follows: To first order in mechanical displacement, tilt of the sensor array or the permanent magnet with respect to the predetermined axis of rotation results in a common mode signal of sensor pairs if the sensors forming a pair are essentially located on the intersection of a plane perpendicular to the axis of rotation and the surface of a cylinder centered at the axis of tilt. For practical occurrences of tilt, namely play of the rotor about some bearing point or tilted mounting of the sensor array or of the magnetic source with respect to the axis of rotation, the axis of tilt and the axis of rotation can be assumed to intersect each other in a point. Consequently, influence of tilt on the measured angle is largely rejected by using difference signals of sensor pairs if the sensors forming a pair are substantially located within a plane perpendicular to the axis of rotation, such that the axis of rotation intersects said plane in the center of each line connecting two sensors of one pair. The better the functions $f_i(z)$ are approximated by their first order Taylor expansion around the nominal positions of the sensors, the better is the rejection of tilt on the measured angle.

[0021] In an exemplified embodiment, a homogeneously magnetized bar magnet, which has the shape of a cuboid of 2mmx3mmx3mm, the first dimension being the distance between the two pole faces, produces a field component which substantially fulfills the conditions as named above for optimum rejection of sensor offset and sensitivity variations as well as for mechanical tolerances in a volume of $(0.6\text{mm})^3$, located some 0.5mm from one of the rectangular surfaces of the magnet. Figure 3 shows the lines of equal magnetic strength of the magnetic field created by the magnet as described above at a distance of 0.5mm from one of the rectangular surfaces of the magnet. The area shown in the Figure is a square of 2mm (2x1000μm) in the center of the rectangular surface, the north/south axis being oriented top/bottom in the Figure. The middle region of this area enclosed by the circle 30 fulfills the conditions as given above.

[0022] In the exemplified embodiment of the inventive arrangement the cuboid magnet is mounted on the rotor such that the rotation axis is parallel to the pole faces of the magnet and runs through the center points of two opposite rectangular surfaces of the magnet and the sensors are arranged e.g. in a square which is oriented perpendicular to the rotation axis, which is distanced from the rectangular surface of the magnet by approximately 0.5mm and in which the sensors of one pair are distanced from each other by not more than approximately 1mm (positioned within the circle 30 indicated in Figure 3).

[0023] Figure 4 shows a further exemplified embodiment of the inventive arrangement. In this embodiment, the stator 3 comprises in addition to the sensor array with visible sensors 4, 5 and 6, a ferromagnetic yoke 11 having the form of a ring within which the sensors are positioned. The yoke 11 fulfills the dual purpose of holding the rotor 2 in place and of shaping the magnetic field of the rotating magnetic source to attain a volume V for locating the sensors in which volume the measured magnetic field component $B_\perp$ complies to the conditions stated above. Being rigidly connected to the sensor array, the yoke 11 reduces changes of the field component $B_\perp$ within V due to movement of the rotor 2 other than rotation about the rotation axis 1.

[0024] The magnetic source according to the embodiment of Figure 4 consists of two cuboid or cylindrical magnets

8 and 9 and of a further ferromagnetic yoke 10 or of a U-shaped permanent magnet, whereby this magnetic source has a north and a south face arranged in substantially the same plane perpendicular to the rotation axis and substantially symmetrical to the rotation axis.

Claims

1. Method for determining the rotation position of a rotor (2) being rotatable around a rotation axis (1) and carrying a magnetic source (2.1, 8/9) creating a magnetic field without a rotational symmetry relative to the rotation axis (1), the method comprising the steps of measuring local components of the magnetic field using stationary sensor means and determining the rotational position of the rotor (2) by comparing quantities measured by the sensor means with a predetermined function of said field component versus the rotation position of the rotor (2),
   characterized
   in that for reducing the influence of external magnetic fields and of sensitivity and offset variations of the sensor means on the accuracy of the determination of the rotation position,
   the sensor means are designed as at least three sensors (4, 5, 6, 7) constituting at least two sensor pairs (4/5, 6/7) wherein the sensors of each sensor pair are sensitive to substantially parallel components of the magnetic field and wherein connecting lines each connecting two sensors of one sensor pair have projections in a plane perpendicular to the rotation axis (1) which are angled relative to each other,
   and differences of the quantities measured by the two sensors of each sensor pair (4/5, 6/7) and at least one ratio of the differences of two pairs are calculated and the at least one ratio of differences is compared with a corresponding predetermined function.

2. Method according to claim 1, **characterized in that** for reducing the influence of mechanical translation of the stationary sensor means and/or the magnetic source (2.1, 8/9) relative to each other or relative to the rotation axis (1), the magnetic source (2.1, 8/9) is designed such that the magnetic field comprises a volume (V) in which the component to be measured by the sensors (4, 5, 6, 7) varies substantially linearly in a plane perpendicular to the rotation axis (1) and according to a function parallel to the rotation axis (1) which function is substantially the same in all locations within said volume (V) and the sensors (4, 5, 6, 7) are positioned in said volume (V) such that each line connecting the two sensors of one sensor pair (4/5, 6/7) is substantially perpendicular to the rotation axis (1).

3. Method according to claim 2, **characterized in that** for reducing the influence of mechanical tilt of the magnetic source (2.1, 8/9) and/or the sensor means relative to the rotation axis (1), the magnetic source is such designed that within said volume (V) the magnetic field varies substantially linearly in a direction parallel to the rotation axis (1) and the sensors (4, 5, 6, 7) are arranged such that each line connecting the two sensors of one sensor pair (4/5, 6/7) is intersected by the rotation axis (1) and divided into two equal halves.

4. Method according to one of claims 1 to 3, **characterized in that** for preventing ambiguity between rotational positions of the rotor (2) differing by an angle of 180°, a plurality of ratios of differences for different couples of sensor pairs is calculated.

5. Method according to one of claims 1 to 3, **characterized in that** for preventing ambiguity between rotational positions of the rotor (2) differing by an angle of 180°, the step of determining the rotation position includes calculating the differences of the measuring signals and the corresponding ratios with a positive or a negative sign.

6. Arrangement for determining the rotational position of a rotor (2) rotatable around a rotation axis (1) with the method according to claim 1, the arrangement comprising a magnetic source (2.1, 8/9) mounted on the rotor (2), a stator (3) with sensor means for measuring the magnetic field created by the magnetic source and means for calculating from the measuring signals of the sensor means the rotation position of the rotor (2),
   characterized
   in that the sensor means comprises at least three sensors (4, 5, 6, 7) arranged in at least two sensor pairs (4/5, 6/7) wherein the sensors of each sensor pair are sensitive to substantially parallel components of the magnetic field and wherein connecting lines each connecting two sensors of one sensor pair (4/5, 6/7) have projections in a plane perpendicular to the rotation axis (1) which are angled relative to each other,
   and **in that** the means for calculating the rotation position comprises means for calculating the differences of the signals of the two sensors of each sensor pair (4/5, 5/6), means for calculating for the at least two sensor pairs a ratio of the differences and means for comparing the ratio of the differences with a corresponding predetermined function of said field component versus the rotation position of the rotor (2).

7. Arrangement according to claim 6, **characterized in that** at least part of the sensors (4, 5, 6, 7) are replaced by a sensor cluster consisting of a plurality of sensors arranged close to each other and **in that** the means for calculating comprises means for calculating a mean value of the measuring signals of the sensors of each sensor cluster.

8. Arrangement according to claim 6 or 7, **characterized in that** the two sensors of each sensor pair (4/5, 6/7) or the sensors of all sensor pairs (4/5, 6/7) are arranged in the same plane perpendicular to the rotation axis (1).

9. Arrangement according to claim 8, **characterized in that** the two sensors of each sensor pair (4/5, 6/7) are arranged such that the line connecting the two sensors intersects the rotation axis (1) and is cut into two equal halves by the rotation axis.

10. Arrangement according to claim 6 or 7, **characterized in that** the sensor means comprises four sensors (4, 5, 6, 7) arranged in the corners of a square, which square is oriented perpendicular and symmetrical to the rotation axis (1).

11. Arrangement according to one of claims 6 to 10, **characterized in that** the sensors (4, 5, 6, 7) are Hall sensors.

12. Arrangement according to one of claims 6 to 11, **characterized in that** the sensors (4, 5, 6, 7) are integrated together with readout and calculating electronics in one die (3).

13. Arrangement according to one of claims 6 to 12, **characterized in that** the magnetic source is a permanent magnet (10) having two opposite pole faces and that the magnet is arranged on the rotor (2) such that the rotation axis (1) goes through the center of the magnet and is parallel to the two pole faces.

14. Arrangement according to one of claims 6 to 12, **characterized, in that** the magnetic source comprises permanent magnet means (8, 9) with two pole faces positioned substantially in one plane and that the permanent magnet means is arranged on the rotor (2) such that the pole faces are substantially perpendicular and substantially symmetrical to the rotation axis (1).

15. Arrangement according to one of claims 6 to 14, **characterized in that** the stator (3) further comprises a stationary, ring-shaped ferromagnetic yoke (11) and **in that** the sensors (4, 5, 6, 7) are arranged within the ring-shaped yoke (11).

Patentansprüche

1. Verfahren zur Bestimmung der Drehstellung eines Rotors (2), der um eine Rotationsachse (1) drehbar ist und eine Magnetfeldquelle (2.1, 8/9) trägt, die ein Magnetfeld ohne Rotationssymmetrie bezüglich der Drehachse (1) erzeugt, wobei das Verfahren die Schritte beinhaltet, lokale Komponenten des Magnetfeldes unter Verwendung ortsfester Sensormittel zu messen und die Drehstellung des Rotors (2) durch Vergleichen von durch die Sensormittel gemessenen Größen mit einer vorgegebenen Funktion der Feldkomponente von der Drehstellung des Rotors (2) zu bestimmen,
dadurch gekennzeichnet,
daß, um den Einfluß von äußeren Magnetfeldern und von Empfindlichkeits- und Driftschwankungen der Sensormittel auf die Genauigkeit der Bestimmung der Drehstellung zu verringern,
die Sensormittel als wenigstens drei Sensoren (4, 5, 6, 7) ausgelegt sind, die wenigstens zwei Sensorpaare (4/5, 6/7) bilden, wobei die Sensoren eines jeden Sensorpaars im wesentlichen parallele Komponenten des Magnetfeldes erfassen, und wobei Verbindungslinien, die jeweils zwei Sensoren eines Sensorpaars verbinden, Projektionen in einer Ebene senkrecht zu der Drehachse (1) haben, die relativ zueinander einen Winkel bilden, und
daß Differenzen der von den zwei Sensoren eines jeden Sensorpaars (4/5, 6/7) gemessenen Größen und wenigstens ein Verhältnis der Differenzen zweier Paare berechnet werden, und daß das wenigstens eine Differenzverhältnis mit einer entsprechenden vorgegebenen Funktion verglichen wird.

2. Verfahren nach Anspruch 1, **dadurch gekennzeichnet, daß**
zur Verringerung des Einflusses einer mechanischen Translation der ortsfesten Sensormittel und/oder der Magnetfeldquelle (2.1, 8/9) relativ zueinander oder relativ zur Drehachse (1) die Magnetfeldquelle (2.1, 8/9) so ausgelegt ist, daß das Magnetfeld ein Volumen (V) aufweist, in dem die von den Sensoren (4, 5, 6, 7) zu messende Komponente sich im wesentlichen linear in einer senkrecht auf der Drehachse (1) verlaufenden Ebene und parallel

zu der Drehachse (1) gemäß einer Funktion verändert, die an allen Orten innerhalb des Volumens (V) im wesentlichen die gleiche ist, und die Sensoren (4, 5, 6, 7) so in dem Volumen (V) angeordnet sind, daß jede die zwei Sensoren eines Sensorpaars (4/5, 6/7) verbindende Linie im wesentlichen senkrecht zu der Drehachse (1) verläuft.

3. Verfahren nach Anspruch 2, **dadurch gekennzeichnet, daß** zur Verringerung des Einflusses einer mechanischen Verkippung der Magnetfeldquelle (2.1, 8/9) und/oder der Sensormittel relativ zur Drehachse (1) die Magnetfeldquelle so ausgelegt ist, daß innerhalb des Volumens (V) das Magnetfeld sich im wesentlichen linear in einer Richtung parallel zur Drehachse (1) verändert und die Sensoren (4, 5, 6, 7) so angeordnet sind, daß jede die zwei Sensoren eines Sensorpaars (4/5, 6/7) verbindende Linie von der Drehachse (1) geschnitten und in zwei gleiche Hälften geteilt wird.

4. Verfahren nach einem der Ansprüche 1 bis 3, **dadurch gekennzeichnet, daß** zum Verhindern einer Mehrdeutigkeit zwischen Drehstellungen des Rotors (2), die sich um einen Winkel von 180° unterscheiden, mehrere Differenzverhältnisse für unterschiedliche Zweiergruppen von Sensorpaaren berechnet werden.

5. Verfahren nach einem der Ansprüche 1 bis 3, **dadurch gekennzeichnet, daß** zur Vermeidung einer Mehrdeutigkeit zwischen Drehstellungen des Rotors (2), die sich um einen Winkel von 180° unterscheiden, der Schritt der Bestimmung der Drehstellung die Berechnung der Differenzen der Meßsignale und der entsprechenden Verhältnisse mit einem positiven oder einem negativen Vorzeichen beinhaltet.

6. Vorrichtung zur Bestimmung der Drehstellung eines um eine Drehachse (1) drehbaren Rotors (2) mit Hilfe des Verfahrens nach Anspruch 1, wobei die Vorrichtung eine auf dem Rotor (2) befestigte Magnetfeldquelle (2.1, 8/9), einen Stator (3) mit Sensormitteln zur Messung des von der Magnetfeldquelle erzeugten Magnetfeldes und Mittel aufweist zur Berechnung der Drehstellung des Rotors (2) aus den Meßsignalen der Sensormittel,
dadurch gekennzeichnet,
daß die Sensormittel wenigstens drei Sensoren (4, 5, 6, 7) aufweisen, die in wenigstens zwei Sensorpaaren (4/5, 6/7) angeordnet sind, wobei die Sensoren eines jeden Sensorpaars im wesentlichen parallele Komponenten des Magnetfelds erfassen, und wobei Verbindungslinien, die jeweils zwei Sensoren eines Sensorpaars (4/5, 6/7) verbinden, Projektionen in einer Ebene senkrecht zur Drehachse (1) haben, die relativ zueinander einen Winkel bilden, und **daß** die Mittel zum Berechnen der Drehstellung Mittel zur Berechnung der Differenzen der Signale der zwei Sensoren eines jeden Sensorpaars (4/5, 5/6), Mittel zum Berechnen eines Verhältnisses der Differenzen für die wenigstens zwei Sensorpaare und Mittel zum Vergleichen des Verhältnisses der Differenzen mit einer entsprechenden vorgegebenen Funktion der Feldkomponente von der Drehstellung des Rotors (2) aufweisen.

7. Vorrichtung nach Anspruch 6, **dadurch gekennzeichnet, daß** wenigstens ein Teil der Sensoren (4, 5, 6, 7) durch ein Sensorcluster ersetzt ist, das aus mehreren in dichtem Abstand zueinander angeordneten Sensoren besteht, und daß die Mittel zur Berechnung Mittel zur Berechnung eines Mittelwerts der Meßsignale der Sensoren eines jeden Sensorclusters umfassen.

8. Vorrichtung nach Anspruch 6 oder 7, **dadurch gekennzeichnet, daß** die zwei Sensoren eines jeden Sensorpaars (4/5, 6/7) oder die Sensoren aller Sensorpaare (4/5, 6/7) in der gleichen, senkrecht zur Drehachse (1) verlaufenden Ebene angeordnet sind.

9. Vorrichtung nach Anspruch 8, **dadurch gekennzeichnet, daß** die zwei Sensoren eines jeden Sensorpaars (4/5, 6/7) so angeordnet sind, daß die die zwei Sensoren verbindende Linie die Drehachse (1) schneidet und von der Drehachse in zwei gleiche Hälften geteilt wird.

10. Vorrichtung nach Anspruch 6 oder 7, **dadurch gekennzeichnet, daß** die Sensormittel vier Sensoren (4, 5, 6, 7) umfassen, die in den Ecken eines Quadrats angeordnet sind, wobei das Quadrat senkrecht und symmetrisch zur Drehachse (1) orientiert ist.

11. Vorrichtung nach einem der Ansprüche 6 bis 10, **dadurch gekennzeichnet, daß** die Sensoren (4, 5, 6, 7) Hall-Sensoren sind.

12. Vorrichtung nach einem der Ansprüche 6 bis 11, **dadurch**

gekennzeichnet, daß die Sensoren (4, 5, 6, 7) in einem Chip (3) zusammen mit einer Auslese- und Berechnungs-Elektronik integriert sind.

13. Vorrichtung nach einem der Ansprüche 6 bis 12, **dadurch gekennzeichnet, daß** die Magnetfeldquelle ein Permanentmagnet (10) ist, der zwei einander gegenüberliegende Polflächen hat, und daß der Magnet so auf dem Rotor (2) angeordnet ist, daß die Drehachse (1) durch die Mitte des Magnets hindurchgeht und parallel zu den gnets hindurchgeht und parallel zu den beiden Polflächen verläuft.

14. Vorrichtung nach einem der Ansprüche 6 bis 12, **dadurch gekennzeichnet, daß** die Magnetfeldquelle Permanentmagnetmittel (8, 9) mit zwei Polflächen aufweist, die im wesentlichen in einer Ebene angeordnet sind, und daß die Permanentmagnetmittel auf dem Rotor (2) so angeordnet sind, daß die Polflächen im wesentlichen senkrecht und im wesentlichen symmetrisch zur Drehachse (1) verlaufen.

15. Vorrichtung nach einem der Ansprüche 6 bis 14, **dadurch gekennzeichnet, daß** der Stator (3) außerdem ein ortsfestes, ringförmiges ferromagnetisches Joch (11) aufweist, und daß die Sensoren (4, 5, 6, 7) innerhalb des ringförmigen Jochs (11) angeordnet sind.

Revendications

1. Procédé pour déterminer la position de rotation d'un rotor (2) pouvant tourner autour d'un axe de rotation (1) et portant une source magnétique (2,1, 8/9) créant un champ magnétique sans symétrie de rotation par rapport à l'axe de rotation (1), le procédé comprenant les étapes de mesure des composantes locales du champ magnétique en utilisant des moyens de détection fixes et de détermination de la position rotationelle du rotor (2) en comparant les quantités mesurées par les moyens de détection avec une fonction prédéterminée de ladite composante de champ fonction de la position de rotation du rotor (2),
caractérisé
en ce que pour réduire l'influence des champs magnétiques extérieurs et de la sensibilité et compenser des variations des moyens de détection sur la précision de la détermination de la position de rotation,
les moyens de détection sont conçus avec au moins trois détecteurs (4, 5, 6, 7) constituant au moins deux paires de détecteurs (4/5, 6/7) dans lesquelles les détecteurs de chaque paire de détecteurs sont sensibles aux composantes sensiblement parallèles du champ magnétique et dans lesquelles les lignes de raccordement reliant chacune deux détecteurs d'une paire de détecteurs ont des projections dans un plan perpendiculaire à l'axe de rotation (1) formant un angle entre chacune d'elles,
et les différences des quantités mesurées par les deux détecteurs de chaque paire de détecteur (4/5, 6/7) et au moins un rapport des différences de deux paires sont calculés et au moins un rapport de différences est comparé avec une fonction correspondante prédéterminée.

2. Procédé selon la revendication 1, **caractérisé en ce que** pour diminuer l'influence de la translation mécanique des moyens de détection fixe et/ou de la source magnétique (2,1, 8/9) entre elles ou par rapport à l'axe de rotation (1), la source magnétique (2,1, 8/9) est conçue de telle sorte que le champ magnétique comprend un volume (V) dans lequel la composante devant être mesurée par les détecteurs (4, 5, 6, 7) varie d'une façon sensiblement linéaire dans un plan perpendiculaire à l'axe de rotation (1) et suivant une fonction parallèle à l'axe de rotation (1), laquelle fonction est sensiblement la même dans toutes les positions à l'intérieur dudit volume (V) et les détecteurs (4, 5, 6, 7) sont positionnés à l'intérieur dudit volume (V) de telle sorte que chaque ligne raccordant les deux détecteurs d'une paire de détecteurs (4/5, 6/7) est sensiblement perpendiculaire à l'axe de rotation (1).

3. Procédé selon la revendication 2, **caractérisé en ce que** pour diminuer l'influence de l'inclinaison mécanique de la source magnétique (2,1, 8/9) et/ou des moyens de détection par rapport à l'axe de rotation (1), la source magnétique est conçue de telle sorte qu'à l'intérieur dudit volume (V) le champ magnétique varie de façon sensiblement linéaire dans une direction parallèle à l'axe de rotation (1) et que les détecteurs (4, 5, 6, 7) sont disposés de telle sorte que chaque ligne raccordant les deux détecteurs d'une paire de détecteur (4/5, 6/7) soit coupée par l'axe de rotation (1) et divisée en deux moitiés égales.

4. Procédé selon l'une des revendications 1 à 3, **caractérisé en ce que** pour éviter l'ambiguïté entre des positions de rotation du rotor (2) différant d'un angle de 180°, une pluralité de rapports de différences pour différents couples

de paires de détecteurs est calculée.

5. Procédé selon l'une des revendications 1 à 3, **caractérisée en ce que** pour éviter l'ambiguïté entre des positions de rotation du rotor (2) différant d'un angle de 180°, l'étape de détermination de la position de rotation comprend le calcul des différences des signaux de mesure et des rapports correspondants avec un signe positif ou négatif.

6. Dispositif pour déterminer la position de rotation d'un rotor (2) pouvant tourner autour d'un axe de rotation (1) avec le procédé selon la revendication 1, le dispositif comprenant une source magnétique (2,1, 8/9) montée sur le rotor (2), un stator (3) avec des moyens de détection pour mesurer le champ magnétique créé par la source magnétique et des moyens pour calculer à partir des signaux de mesure des moyens de détection la position de rotation du rotor (2),
caractérisé
en ce que les moyens de détection comprennent au moins trois détecteurs (4, 5, 6, 7) disposés en au moins deux paires de détecteurs (4/5, 6/7) dans lesquelles les détecteurs de chaque paire de détecteurs sont sensibles à des composantes sensiblement parallèles du champ magnétique et dans lesquelles les lignes de raccordement reliant chacune deux détecteurs d'une paire de détecteurs (4/5, 6/7) ont des projections dans un plan perpendiculaire à l'axe de rotation (1) formant un angle entre chacune d'elles,
et **en ce que** les moyens de calcul de la position de rotation comprennent des moyens pour calculer les différences des signaux des deux détecteurs de chaque paire de détecteurs (4/5, 5/6), des moyens pour calculer pour au moins les deux paires de détecteurs un rapport des différences, et des moyens pour comparer le rapport des différences avec une fonction correspondante prédéterminée de ladite composante de champ en fonction de la position de rotation du rotor (2).

7. Dispositif selon la revendication 6, **caractérisé en ce qu'**au moins une partie des détecteurs (4, 5, 6, 7) est remplacée par un faisceau de détection constitué d'une pluralité de détecteurs placés à proximité les uns des autres et **en ce que** les moyens de calcul comprennent des moyens pour calculer une valeur moyenne des signaux de mesure des détecteurs de chaque faisceau de détecteurs.

8. Dispositif selon la revendication 6 ou 7, **caractérisé en ce que** les deux détecteurs de chaque paire de détecteurs (4/5, 6/7) ou les détecteurs de toutes les paires de détecteurs (4/5, 6/7) sont disposés dans le même plan perpendiculaire à l'axe de rotation (1).

9. Dispositif selon la revendication 8, **caractérisé en ce que** les deux détecteurs de chaque paire de détecteurs (4/5, 6/7) sont disposés de telle sorte que la ligne raccordant les deux détecteurs croise l'axe de rotation (1) et soit coupée en deux moitiés égales par l'axe de rotation.

10. Dispositif selon la revendication 6 ou 7, **caractérisé en ce que** les moyens de détection comprennent quatre détecteurs (4, 5, 6, 7) disposés dans les coins d'un carré, lequel carré est orienté perpendiculairement et symétriquement à l'axe de rotation (1).

11. Dispositif selon une des revendications 6 à 10, **caractérisé en ce que** les détecteurs (4/5, 6/7) sont des détecteurs Hall.

12. Dispositif selon une des revendications 6 à 11, **caractérisé en ce que** les détecteurs (4, 5, 6, 7) sont intégrés ensemble avec affichage et électronique de calcul dans une matrice unique (3).

13. Dispositif selon une des revendications 6 à 12, **caractérisé en ce que** la source magnétique est un aimant permanent (10) avec deux faces polaires opposées et que l'aimant est disposé sur le rotor (2) de telle sorte que l'axe de rotation (1) passe à travers le centre de l'aimant et soit parallèle aux deux faces polaires.

14. Dispositif selon une des revendications 6 à 12, **caractérisé en ce que** la source magnétique comprend des moyens formant aimant permanent (8, 9) avec deux faces polaires disposées sensiblement sur un même plan, et **en ce que** les moyens formant aimant permanent sont disposés sur le rotor (2) de telle sorte que les faces polaires soient sensiblement perpendiculaires et sensiblement symétriques à l'axe de rotation (1).

15. Dispositif selon une des revendications 6 à 14, **caractérisé en ce que** le stator (3) comprend en outre une traverse (11) ferromagnétique de forme annulaire, fixe, et **en ce que** les détecteurs (4, 5, 6, 7) sont disposés à l'intérieur de la traverse de forme annulaire.

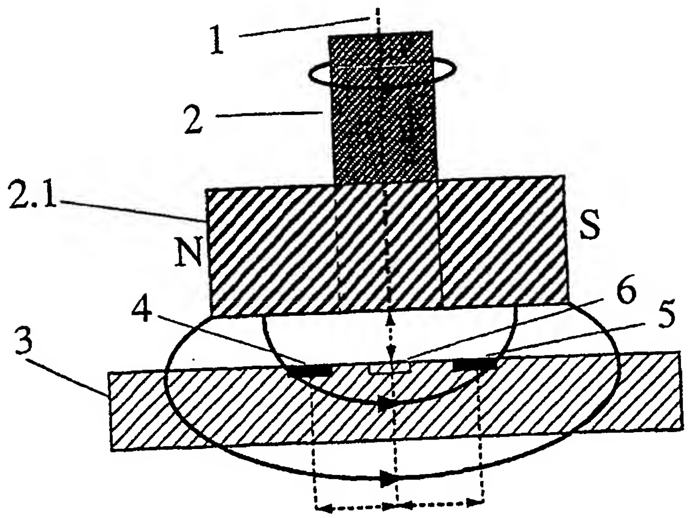

Figure 1

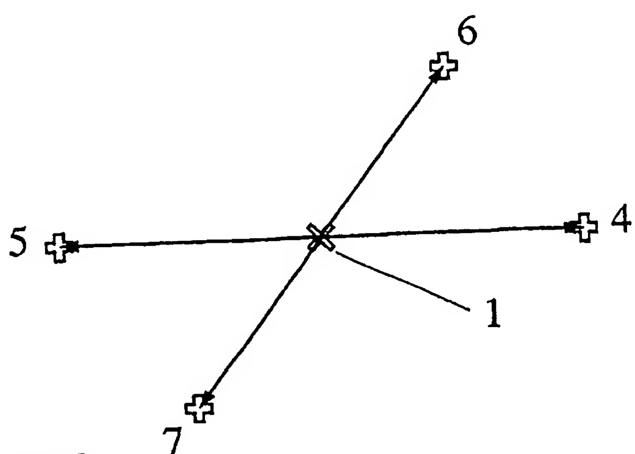

Figure 2

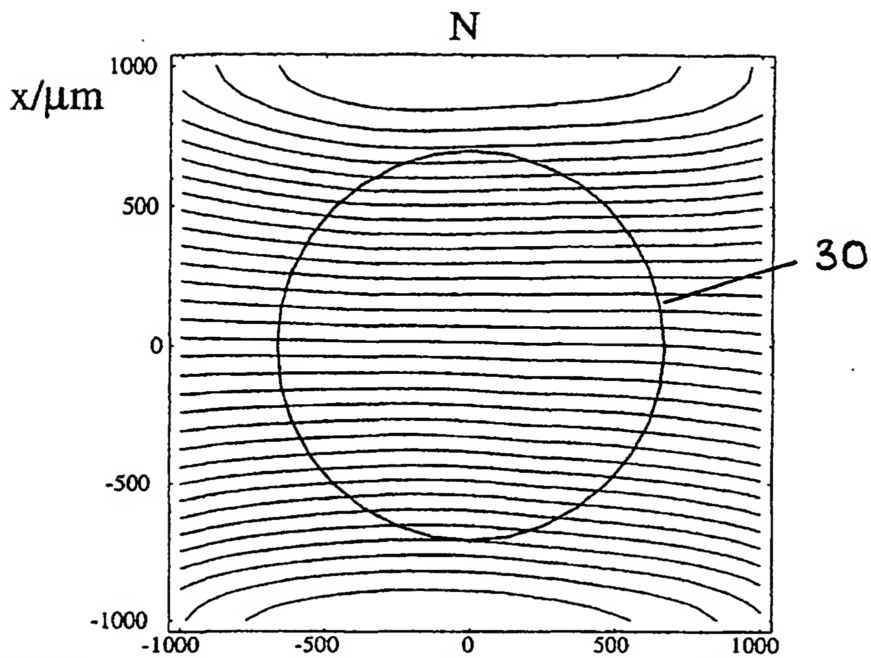

Figure 3

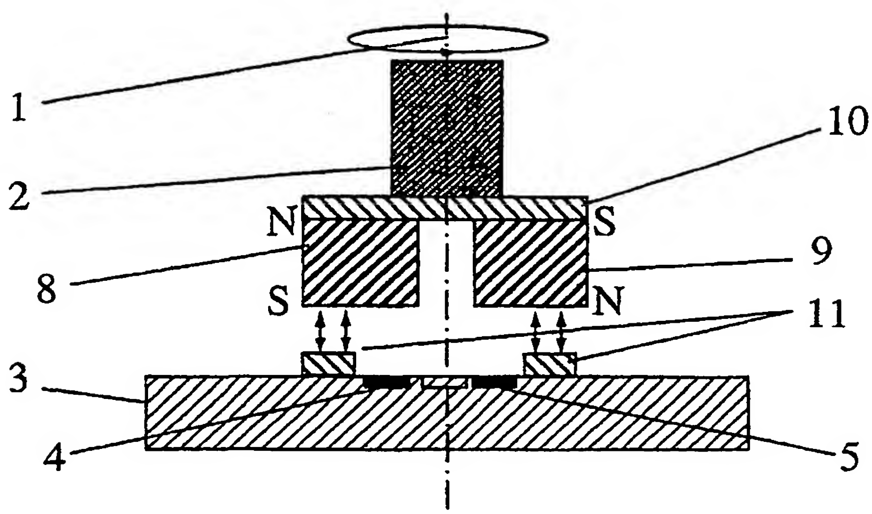

Figure 4